

Recent Advances in Wide-Band Polarimetric and Multi-Baseline Interferometry

Jakob J. van Zyl, Yunjin Kim, and Robert N. Treuhaft

Jet Propulsion Laboratory, 264-601
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109 USA
Phone/Fax: 818-354-1365/818-354-0368; email: jacobv@kalfie.Jpl.Nasa.Gov

Abstract

This paper describes the first fixed-baseline polarimetric interferometry, achieved with Jet Propulsion Laboratory's (JPL) TOPSAR radar with co- and cross-polarized signals. It also describes demonstrations of combinations of multi-baseline radar interferometry and polarimetry for vegetated land surfaces. It was found that TOPSAR co- and cross-polarized interferometric heights differed by as much as 10 m, indicating different scattering mechanisms for each polarization combination. Recent results in combining interferometry and polarimetry with a quantitative physical model suggest the potential 4-m absolute vegetation height determination, when fully polarimetric interferometry becomes routinely available on TOPSAR.

1 Introduction

Fixed-baseline radar interferometry was first envisioned with a single transmit-receive polarization at each end of the baseline[1]. Polarimetric interferometry, realized by transmitting and receiving all polarizations at each end of the baseline, responds to polarization-dependent scattering mechanisms. The experiments described here demonstrate that scattering mechanisms at co- and cross-polarization exhibit effective interferometric phase centers which can differ by as much as 10 m. Fully polarimetric repeat-pass demonstrations[2] also suggest phase center separations of a similar order. Ultimately, fully polarimetric fixed-baseline interferometry can be used to quantitatively estimate parameters describing vegetated land surfaces[3, 4]. A preliminary indication of, for example, the estimated vegetation height accuracy is obtained by combining interferometry and zero-baseline polarimetry. Multi-baseline interferometry is needed to supply the number of observations required for parameter estimation. The 2.5-m and 5-m (realized with ping-pong signals) TOPSAR interferometric baselines were used along with the ratio of HHHH/VVVV power. It was found that height accuracies of $\approx 4\text{m}$ could be achieved if an oriented-vegetation correction was made based on the HHVV phase.

2 Dual Polarized TOPSAR Interferometry

A dual-polarized, fixed-baseline interferometer was implemented during the AIRSAR 1993 South American campaign by transmitting out of the polarimetric C-band AIRSAR antenna, and receiving through the two vertically polarized C-band TOPSAR antennas. Figure 1 shows the differences between interferometric elevations at VVVV and HVHV polarizations. Differences of the order of 10 m and less were observed. The data were taken at C-band. The interferometric height differences are consistent with at least two scenarios: 1) a randomly oriented vegetation volume (contributing most of the HVHV return) and a surface reflection (contributing the VVVV return); and 2) an oriented vegetation volume in which the extinction properties are difference for VVVV and HVHV. Without acquiring data from more baselines and fully polarimetric interferometry, it is difficult to discriminate between these two, and other, possibilities. Demonstrations with fully polarimetric TOPSAR are now underway, but are still in the testing phase. The primary conclusion from the current VVVV-HVHV demonstration is that few to ten meter effective scattering centers will characterize future fully polarimetric interferometric data. The scattering mechanisms inducing these phase centers will be studied by parameter estimation approaches, as indicated below.

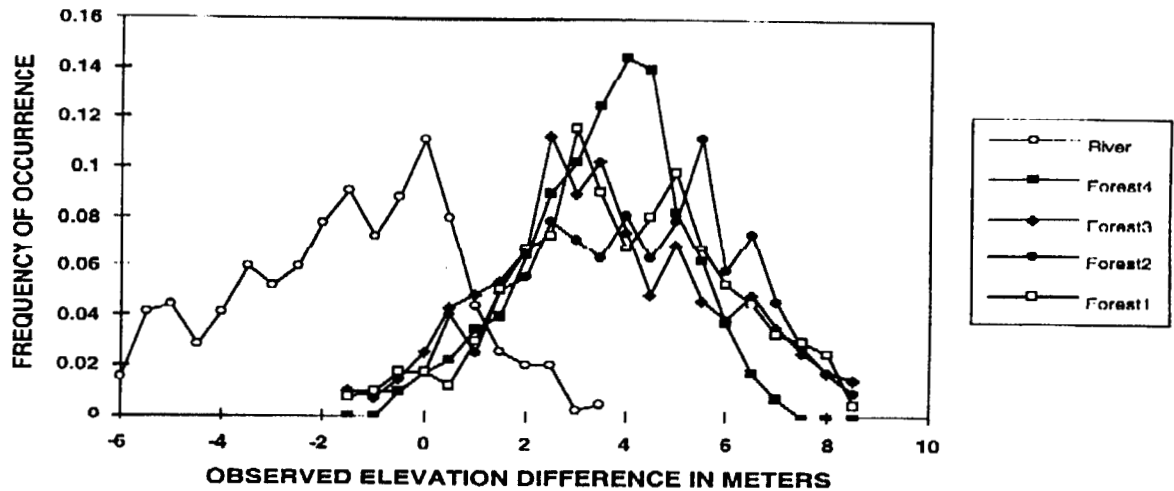


Figure 1: VVVV-HVHV interferometric elevation differences from Surinam Rain Forest.

3 Multi-Baseline TOPSAR Interferometry with Polarimetry

Multi-baseline interferometry has a distinct advantage in parameter estimation because it adds new observations, but does not introduce any new parameters (scattering mechanisms are the same for each baseline). A two-baseline VVVV interferometric demonstration for the estimation of tree height was performed over the BOREAS Southern Study Site[4]. In addition to the amplitude and phase from a 2.5- and 5-m baseline, the zero-baseline HHHH/VVVV ratio was used in a simple model describing a randomly oriented volume over a flat slightly-rough-scattering surface. It was found that the comparison of tree height with field measurements improved if a correction was applied to the HHHH/VVVV power ratios for orientation effects in the volume. This correction was based on the relationship between the HHVV phase and the HHHH/VVVV power ratio for dipoles, and therefore was not rigorously correct for forest vegetation, but was applied to demonstrate that the data are more consistent with an oriented, rather than randomly oriented volume component. Figure 2 shows

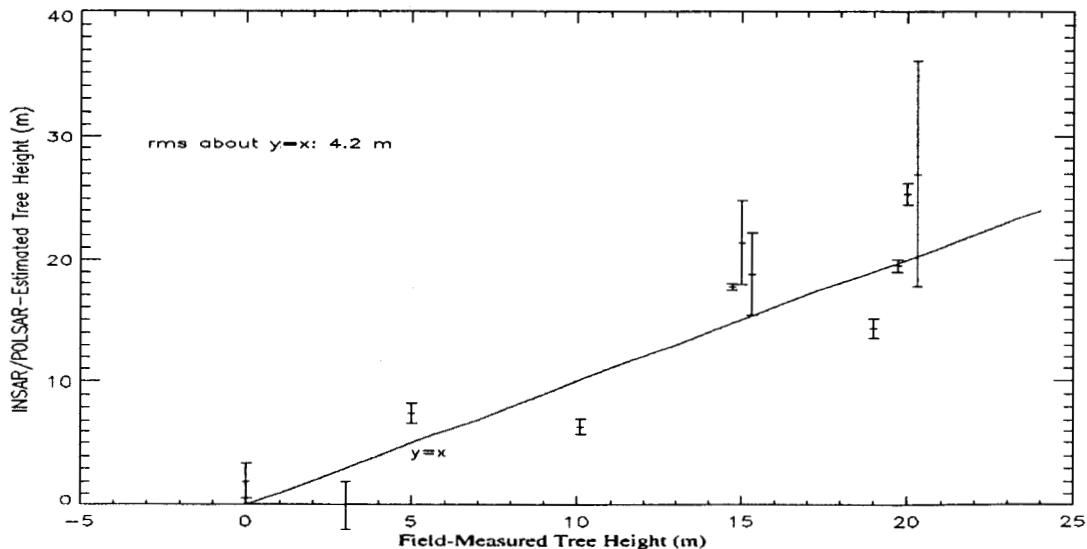


Figure 2: Tree heights estimated from 2-baseline interferometry and polarimetry, versus field measurements.

the interferometry + polarimetry-estimated tree heights versus field measurements. The figure suggests that 4-m

tree height accuracies may be obtained with multi-baseline interferometry and polarimetry. As before, in order to unambiguously identify scattering mechanisms and realize this accuracy, fully polarimetric multi-baseline interferometry will be necessary.

4 Conclusions

The first fixed-baseline polarimetric interferometric demonstration shows effective phase centers separated by up to 10 m between VVVV and HVHV interferometry. These separations be due to different levels of ground contribution or oriented volume contributions. A multi-baseline VVVV interferometric demonstration supplemented by zero-baseline polarimetry showed that tree height parameters may potentially be estimable with 4-m accuracy, accounting for oriented vegetation characteristics. Fully polarimetric, multi-baseline interferometry, available with TOPSAR in the near future, will help to unambiguously describe vegetated land surfaces.

5 Acknowledgment

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

References

- [1] H.A. Zebker, S.N. Madsen, J. Martin, K.B. Wheeler, T. Miller, Y. Lou, G. Alberti, S.Vetrella, and A. Cucci, "The TOPSAR Interferometric Radar Topographic Mapping Instrument," *IEEE Transactions on Geoscience and Remote Sensing*, **30**, 933-940, 1992.
- [2] S.R. Cloude and K.P. Papathanassiou, "Polarimetric SAR Interferometry," *IEEE Trans. Geosci. Remote Sensing*, in press, 1998.
- [3] R. N. Treuhaft, and S. R. Cloude, "Vegetation Structure from Polarimetric Interferometry," *IEEE Trans. Geosci. and Rem. Sens.*, in review, 1998.
- [4] R. N. Treuhaft, "The Vertical Structure of Vegetated Land Surfaces from Interferometric and Polarimetric Radar," in preparation, 1998.